This paper is not an official publication and reference must not be made to it in any printed publication without reference to the author.

TEMPERATURE - LEAF NUMBER RELATIONS FOR WINTER BARLEY, 1984/85

AGRICULTURAL MEMORANDUM NO. 1066. M N HOUGH

Summary

An experiment in 1984/5 was performed to provide high resolution data on the effect of sowing date on the leaf development of winter barley in relation to air temperature. Leaf number for sowings a week apart in September and October were related to temperatures accumulated above bases of 0, 1, 3 and 5°C. Weekly leaf number increments were related to weekly mean temperature to find the base temperature for growth. The maximum leaf number was related to temperature conditions in the period after sowing.

Introduction

Several sets of winter barley leaf number/temperature data between 1981 and 1984 are now available for sites in Yorkshire. At each site, irrespective of soil type or crop variety, the relation between leaf number and thermal time (sums of daily mean screen air temperatures above 0°C) can be represented by three straight lines (for September sowings) or two straight lines (October sowings) (Ag. Memo. 1002). The autumn and spring growth periods show faster leaf production in thermal time than the winter period which covers November to February. As yet it is not known if this is a crop phenomenon, or else due to a different relation between temperatures measured in the screen and at plant level. In 1984/85 an experiment was performed to test the timing of the phases of growth for plants sown at frequent intervals.

Site and Methods

The site was at Harrogate using a small plot 60cm x 60cm on a soil of the Dunkeswick soil association, fine loam over clay and not free draining. Seed of Panda winter barley was sown on 8, 15, 22 and 29 September 1984 and on 6, 13 and 27 October. A final sowing was made on 24 February 1985. Seed was sown singly by hand in north-south rows. Weeding was by hand and all the plot had about 100 kg/ha of nitrogen during early April. Two plants were chosen from each sowing date and measurements of the leaf length and number were made. As each leaf appeared a coloured loop of wire was attached to it so that it could be recognised at each visit. The visible portion of each leaf was measured by ruler from the ligule of the subtending next oldest leaf until it was fully emerged. Air temperature was measured at 1.2m above ground using standard maximum and minimum thermometers in a screen sited 2m to the north of the plot.

Results

1. Comparison of the methods for evaluating accumulated temperature/thermal time.

For base zero we have two sorts of temperature accumulation:-

a. Sum of the mean temperatures above 0°C ('thermal time'). Mean temperature is defined as half of the sum of the 24 hour maxima and minima.

b. The calculation procedure based upon Meteorological Office leaflet 10.

FH2B

a. and b. are by definition equal for a 24 hour period when the minimum temperature does not fall below zero. During cold weather when the temperature drops below 0°C, a. will be less than b. In the winter of 1984/85 freezing weather mainly occurred in February and by 1 May b. exceeded a. by 24°C days.

2. Base Temperature

Some previous work on winter barley (Kirby et al (1982)) has suggested that the base temperature for starting temperature accumulations should be near 5°C for early sowings and decrease to about 0°C for later sowings. This was tested here by regressing the leaf number data for the eight sowing dates against thermal time (base 0°C), and for accumulated temperature above base 1, 3 and 5°C. Table 1 shows the correlation coefficients found. All the correlation coefficients are very high and there is no obvious variation due to base temperature, with any of the bases from 0 to 5°C being suitable for use with a linear correlation analysis. However plots of the data show a systematic change in the residuals from the regression line which take place in a way that does not alter the correlation coefficient. This technique is therefore not always suitable to determine the base and the alternative way which regresses the rate of development against mean temperature was used instead.

The weekly increase in leaf number was found for the sowings and plotted against the weekly mean temperature. Figures 1 to 4 show the data for sowings 1, 2 and 6, 7. This shows that the leaves grew at temperatures down to 0°C with no variation in the base for any of the sowing dates. The only exception was the February sowing which had a base temperature near 4.5°C.

A base temperature of 0°C is therefore used in the analysis of sowings 1 to 7.

3. Leaf Number/Thermal Time relations

Figure 5 shows leaf number against thermal time for the seven sowings. Each line represents the same plant in each sowing. The lines are fitted by eye. The earlier sowings are best represented by three lines and it is seen in the figure that the duration of the first linear portion in the autumn becomes progressively shorter as the sowing date gets later, until by sowing 7 only two lines are necessary. The changes of slope in autumn and spring (at about 660°Cd and 1030°Cd from 8 September) take place simultaneously for all the sowings. The dates of these changes in slope are about the first week in November and the third week in February. At present it is not known if the changes of slope are due to an internal plant response or due to a change in the relation between screen and plant temperatures.

Some possible explanations are:-

a. A daylength effect. The daylength is about 9.5 hrs in early November and mid February at 54°N. The plants would have to respond at any growth stage.

b. A radiation balance effect. The climatological global short wave radiation is below about 5.0 MJ/M^2/day between these dates which is about the same size, or smaller than the long wave radiation loss. Hence the soil surface has a net loss of energy during this period which could lead to reduced temperature accumulations at plant level compared to screen level. Ag. Memo 1017 by E Spackman in fact reports that this is the case.

c. A crop nutrition effect (S Evans, personal communication). As soil temperatures fall in autumn then the rate of production of nitrogen within the soil decreases. This restricts the available N to the plant which therefore slows down its growth. Also the changeover from seminal to adventitious roots can occur in this period and the root system may not be sufficient in autumn to

maintain an earlier rate of development. Some experiments currently in progress aim to test a. and b. above and early results support the second explanation b.

4. Final Leaf Number

One striking feature in figure 5 is the great similarity in development rates for all the sowings and how synchronism of leaf development is achieved by reductions in final leaf number as the sowings become later. Hence the flag leaf finishes expanding within 10 days for sowings made up to 7 weeks apart.

An estimate of the final leaf number can be made at the end of autumn by using Weir et al (1984). The basic idea is that when vernalisation is complete then the plants switch from a vegetative to a reproductive state and so no more leaves can be produced. This is almost certainly an oversimplification (Kirby et al (1986)), but at least it allows for the fact that colder places, or colder than normal autumn weather causes a lower final leaf number.

The vernalisation process proceeds at a maximum rate at about 7°C and declines to zero above about 17°C. This is the typical range of temperature which is experienced in UK after sowing. Although temperature is the major factor, daylength also has some effect and shorter days hasten vernalisation. Correlations were found between the final leaf number and mean temperature after sowing and also with a vernalisation factor (mean temperature x daylength)/20 (from Weir et al (1984)). The mean temperature was found for 3, 5 and 7 weeks after sowing and the correlations with mean temperature were 0.92, 0.99 and 0.97 respectively. Not surprisingly an inclusion of the daylength factor did little to improve the correlations. However, when data for other sites and years (Great Kendale, Skipwith and Hooton Pagnell) are included the correlations with mean temperature become 0.84, 0.87 and 0.80 for 3, 5, 7 weeks after sowing. If the daylength factor is also included with the best of these correlations (for 5 weeks) then the correlation increases to 0.90.

The following equation is proposed:-

$$N = 7.22 + 1.126\ T^*$$

N = final leaf number of winter barley plants of varieties Akin to Panda and Igri.

T * = (mean air temperature 5 weeks after sowing) x (daylength 3 weeks after sowing)/20.

Conclusions

1. The sum of positive daily mean temperatures ('thermal time') was only 24°Cd less than accumulated temperature above 0°C.

2. Based upon weekly leaf growth increments all the sowings in September and October had a base temperature of 0°C.

3. Two or three straight lines are required to describe the leaf number/thermal time relationships of winter barley.

4. The final leaf number can be related to mean temperature 5 weeks after sowing or to a photothermal quantity in the same period.

TABLE 1

Correlation coefficients between leaf number and temperature accumulations above base 0, 1, 3 and 5°C.

Base °C	Sowing Date							
	8/9	15/9	22/9	29/9	6/10	13/10	27/10	24/2
0	0.995	0.983	0.994	0.992	0.994	0.996	0.994	0.994
1	0.995	0.980	0.994	0.993	0.995	0.997	0.995	0.995
3	0.992	0.967	0.961	0.993	0.996	0.997	0.997	0.997
5	0.983	0.989	0.991	0.991	0.993	0.995	0.995	0.998

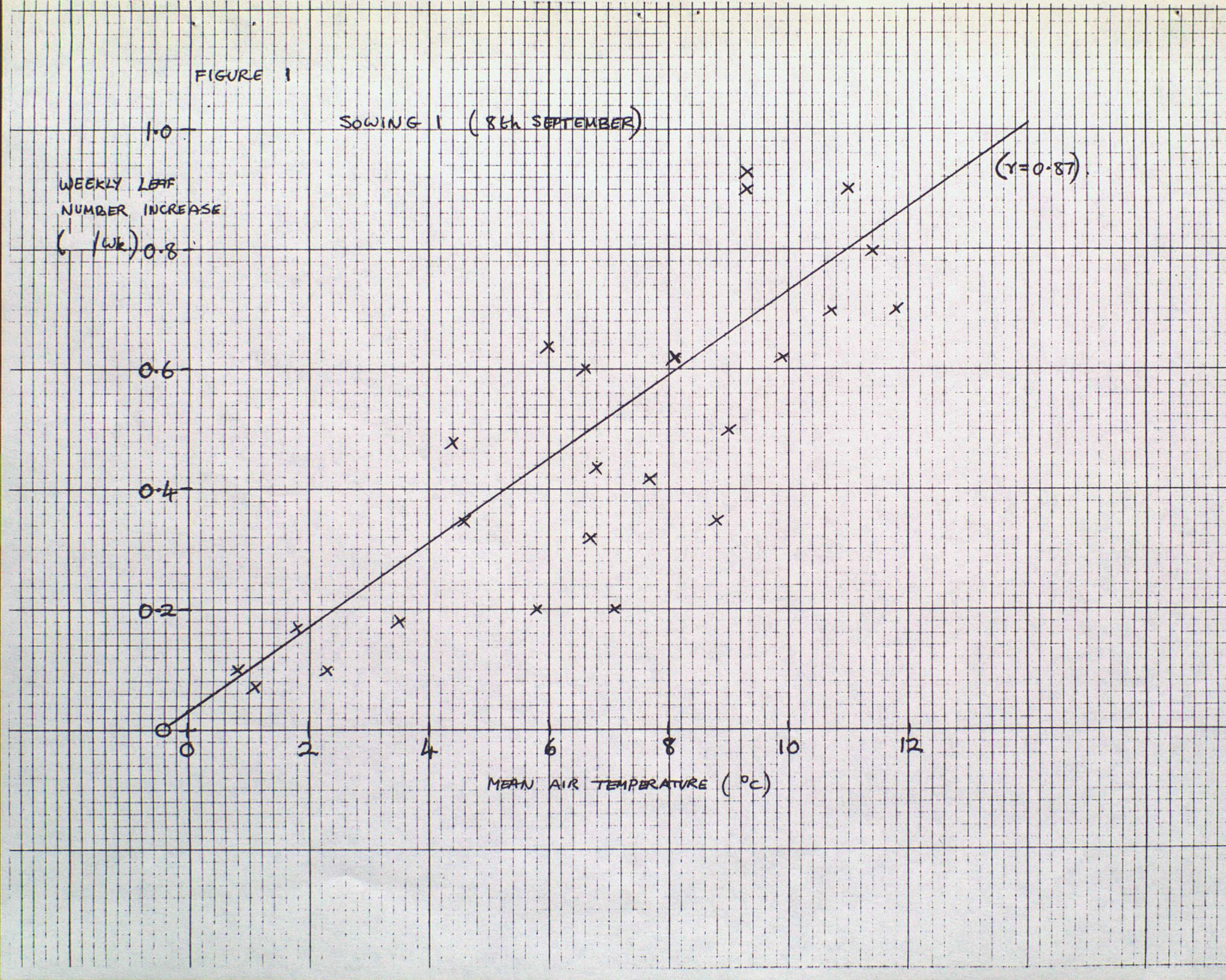
References

Kirby, E J M, Appleyard, M and Fellowes, G. 1982. Effect of sowing date on the temperature response of leaf emergence and leaf size in barley. Plant, Cell and Environment, 5, 477-484.

Kirby, E J M and 17 others 1986. An experimental survey of the development of Avalon wheat grown over a range of sites and sowing dates in England and Scotland. II. Leaf and spikelet initiation on the main shoot. Submitted to J. Agric. Sci. Camb.

Weir, A H; Bragg, P L;Porter, J R and Rayner, J H 1984. A winter wheat crop simulation model without water or nutrient limitations. J. Agric. Sci. Camb. 102, 371-382.

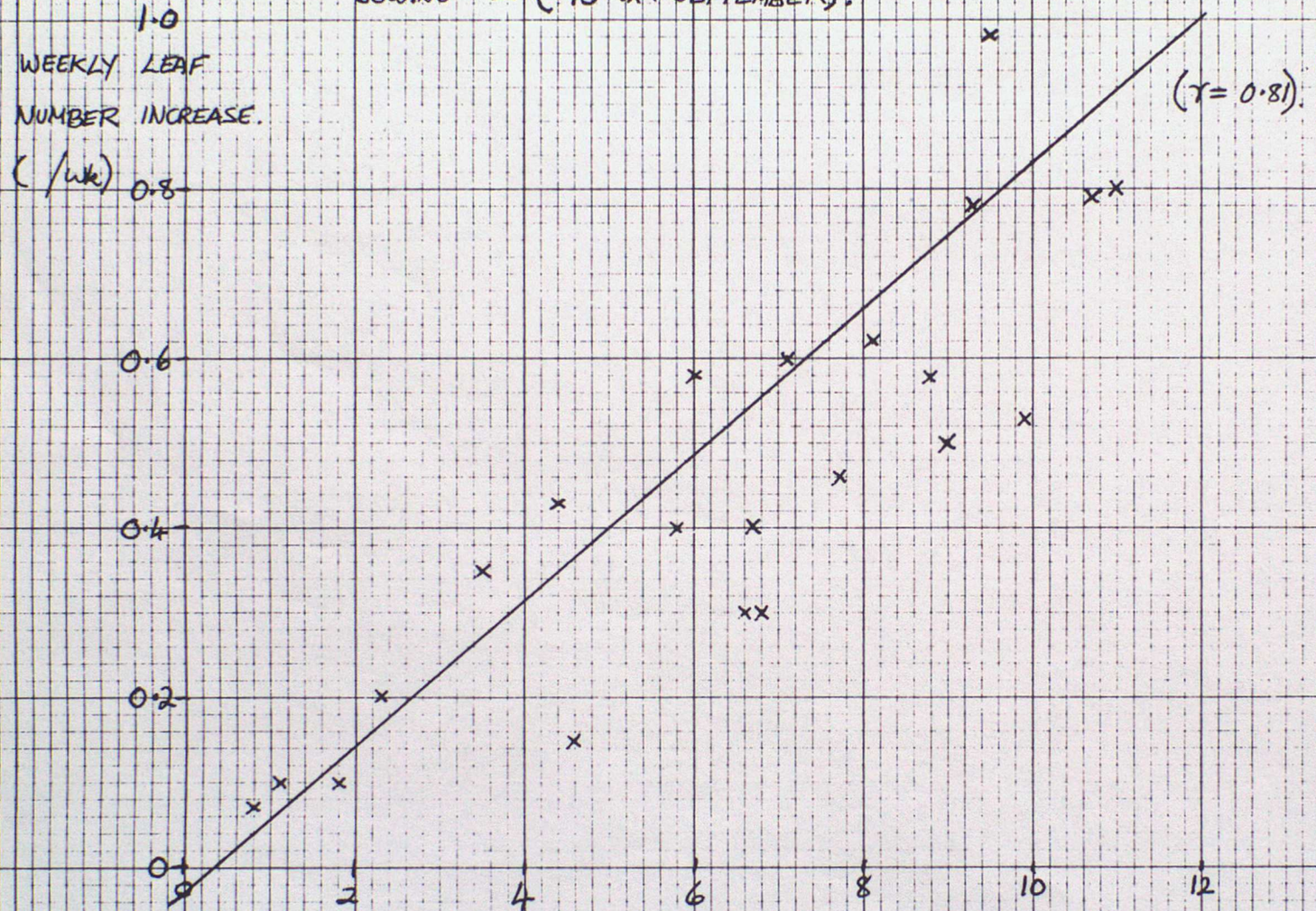
FIGURE 1


SOWING 1 (8th SEPTEMBER)
(r = 0·87)
WEEKLY LEAF NUMBER INCREASE (/Wk.)
1·0
0·8
0·6
0·4
0·2
0
2
4
6
8
10
12
MEAN AIR TEMPERATURE (°C)

E.R.

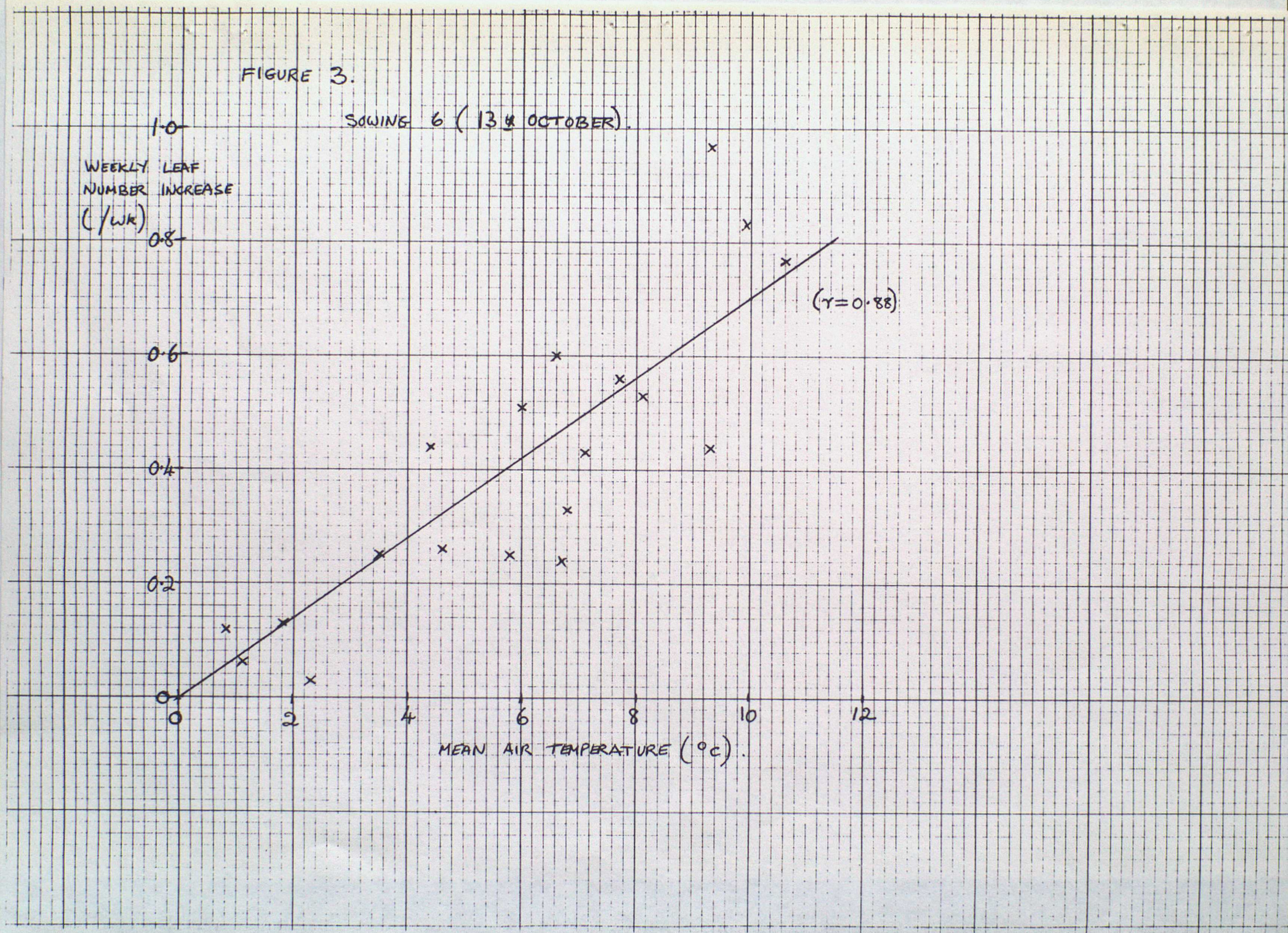
FIGURE 2.

SOWING 2 (15 th. SEPTEMBER).



E.R.

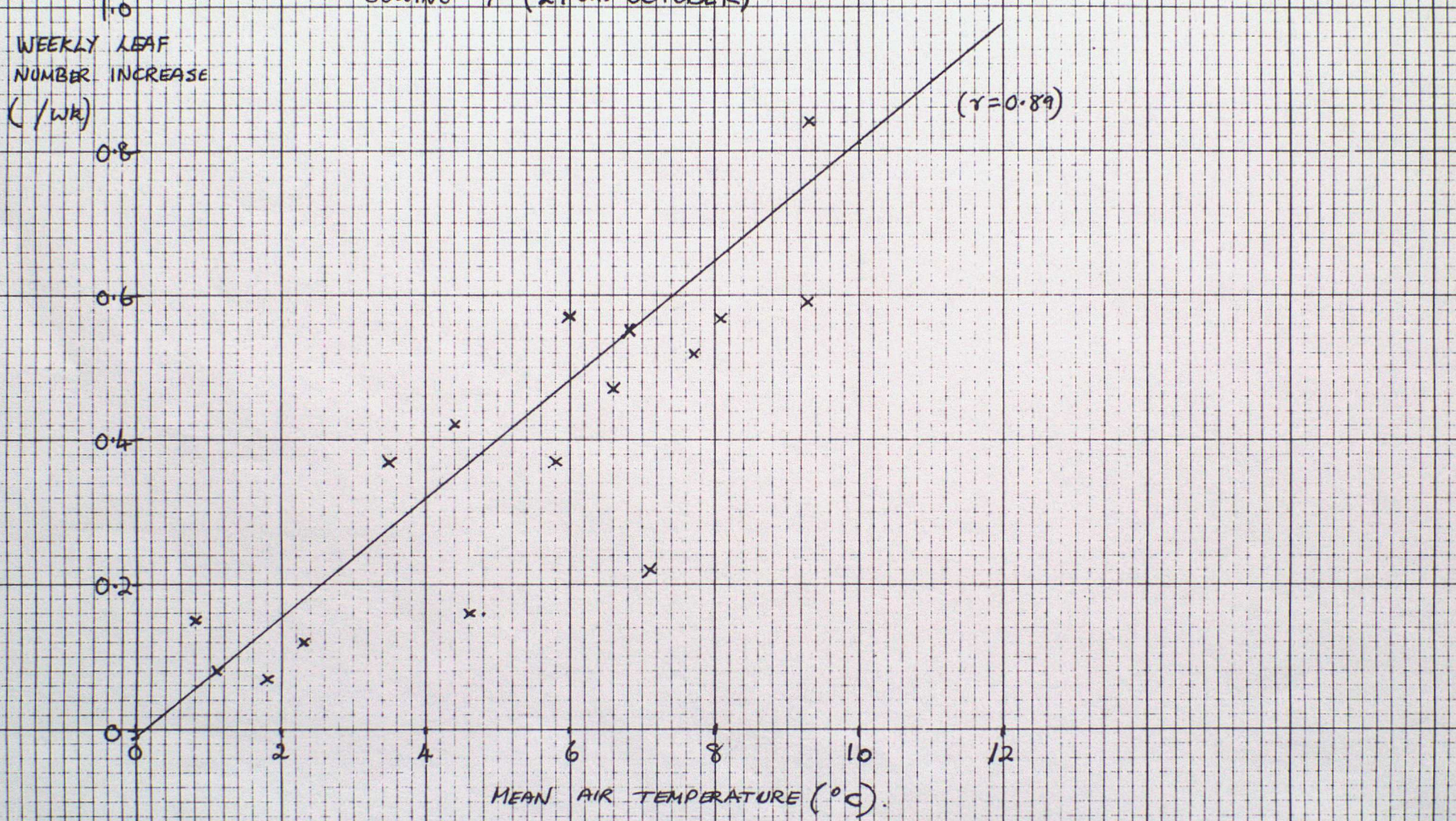
FIGURE 3.


SOWING 6 (13th OCTOBER).
WEEKLY LEAF NUMBER INCREASE (/WK)
1·0
0·8
0·6
0·4
0·2
0
(r=0·88)
0
2
4
6
8
10
12
MEAN AIR TEMPERATURE (°C).

E.R.

FIGURE 4

SOWING 7 (27th. OCTOBER)



E.R.

FIGURE 5.

LEAF NUMBER/THERMAL TIME RELATIONSHIPS FOR 7 SOWING DATES.